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Berry et al.

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(54) **BATTERY PROTECTION IN AN ELECTRIC VEHICLE**

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B62D 25/20 (2006.01)

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CPC ***B60K 1/04*** (2013.01); ***B62D 25/2072*** (2013.01); *B60K 2001/0438* (2013.01)

(58) **Field of Classification Search**
CPC B60K 1/04; B60K 2001/0438; B62D 25/2072; B60Y 2306/01
See application file for complete search history.

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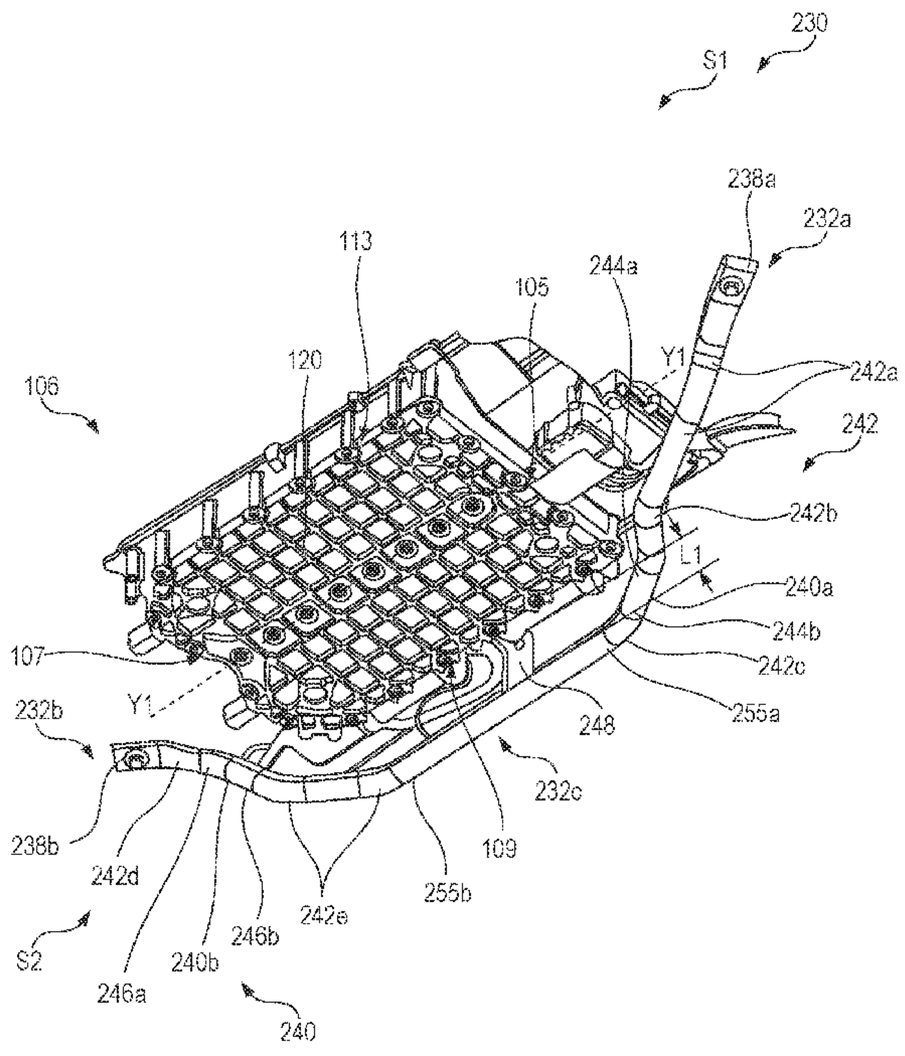
(57) **ABSTRACT**

The present disclosure is directed to a slider bar to protect a battery pack of a vehicle. The battery pack is housed on an underbody in between the vehicle's front and rear axles. The battery pack protrudes towards the ground. The battery pack can optionally be covered by a shield that has a slot through which the slider bar extends outwards towards the ground. The slider bar is coupled to the underbody near the battery pack. The slider bar is positioned lower than the battery pack such that in an event of the vehicle bottoming out, the impact will be absorbed by the slider bar instead of the battery pack. Thereby, the slider bar protects the battery pack from scraping/scratching the ground.

19 Claims, 7 Drawing Sheets



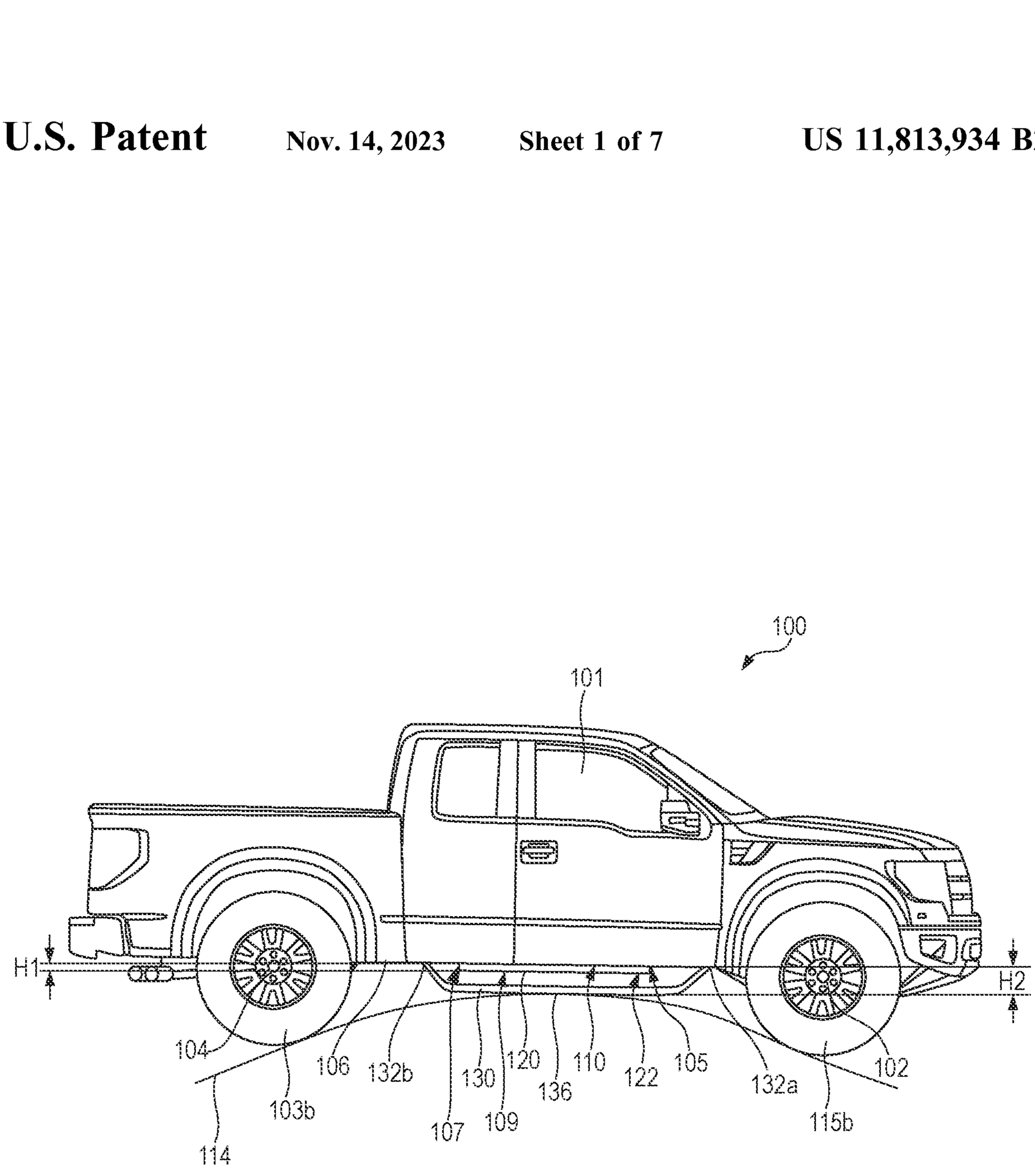

100
101
H1
H2
104
106
132b
130
120
110
122
105
102
103b
107
109
136
132a
115b
114

FIG. 1A

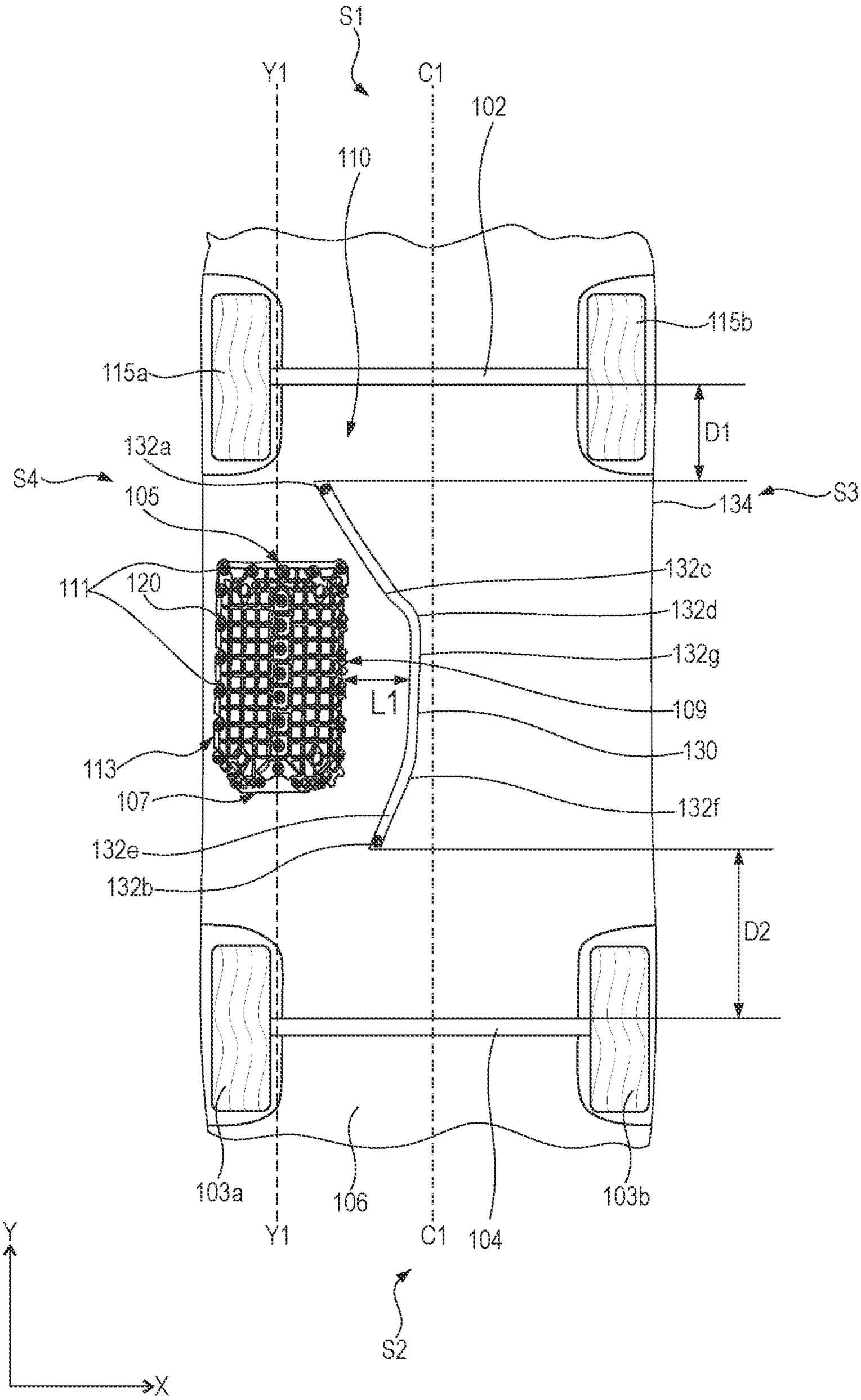

S1
Y1
C1
102
110
115b
115a
D1
132a
S4
105
134
S3
111
120
132c
132d
132g
L1
109
130
113
107
132f
132e
132b
D2
103a
106
104
103b
Y
X
S2

FIG. 1B

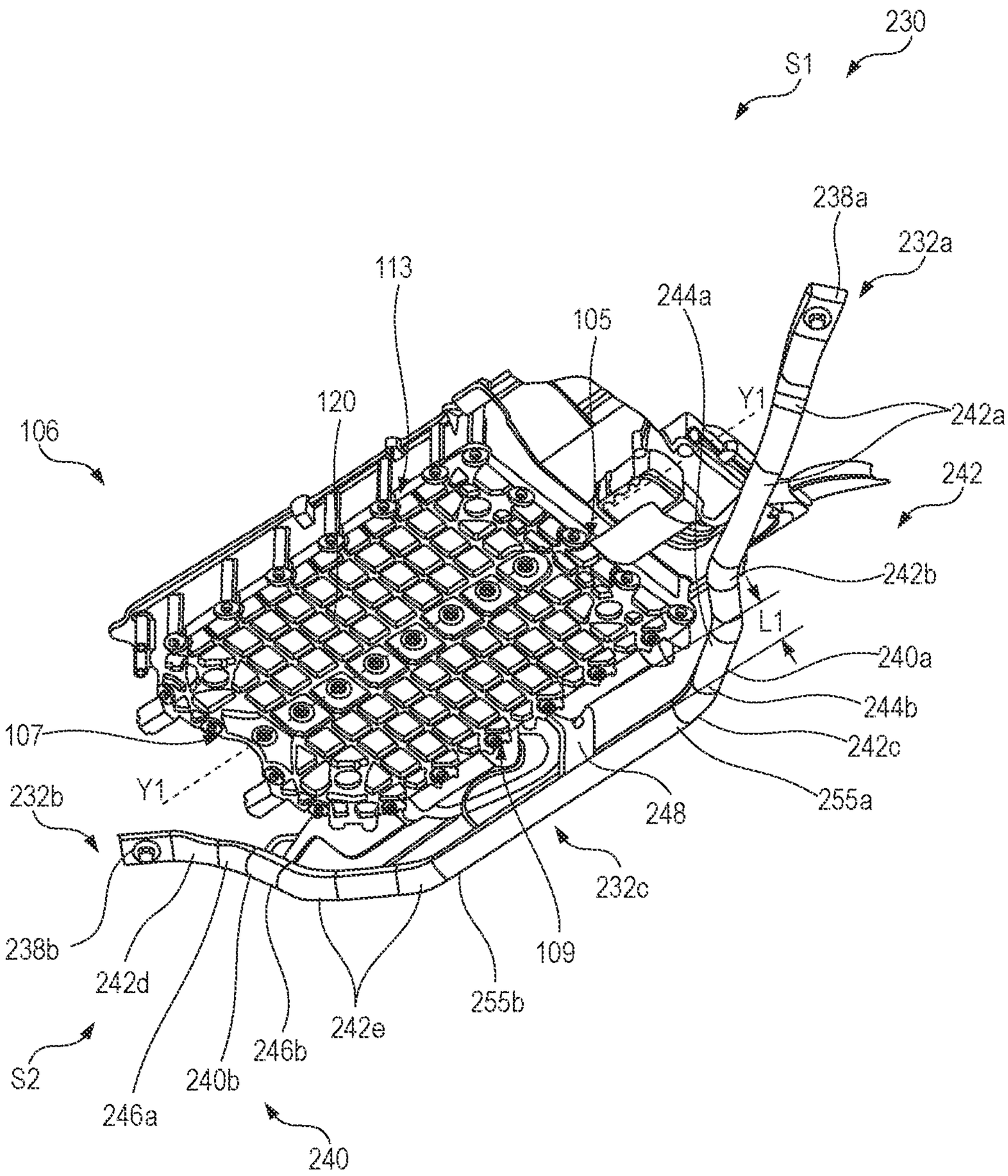

230
S1
238a
232a
113
105
244a
120
Y1
242a
106
242
242b
L1
240a
244b
107
242c
Y1
232b
248
255a
232c
238b
242d
109
255b
242e
246b
S2
240b
246a
240

FIG. 2

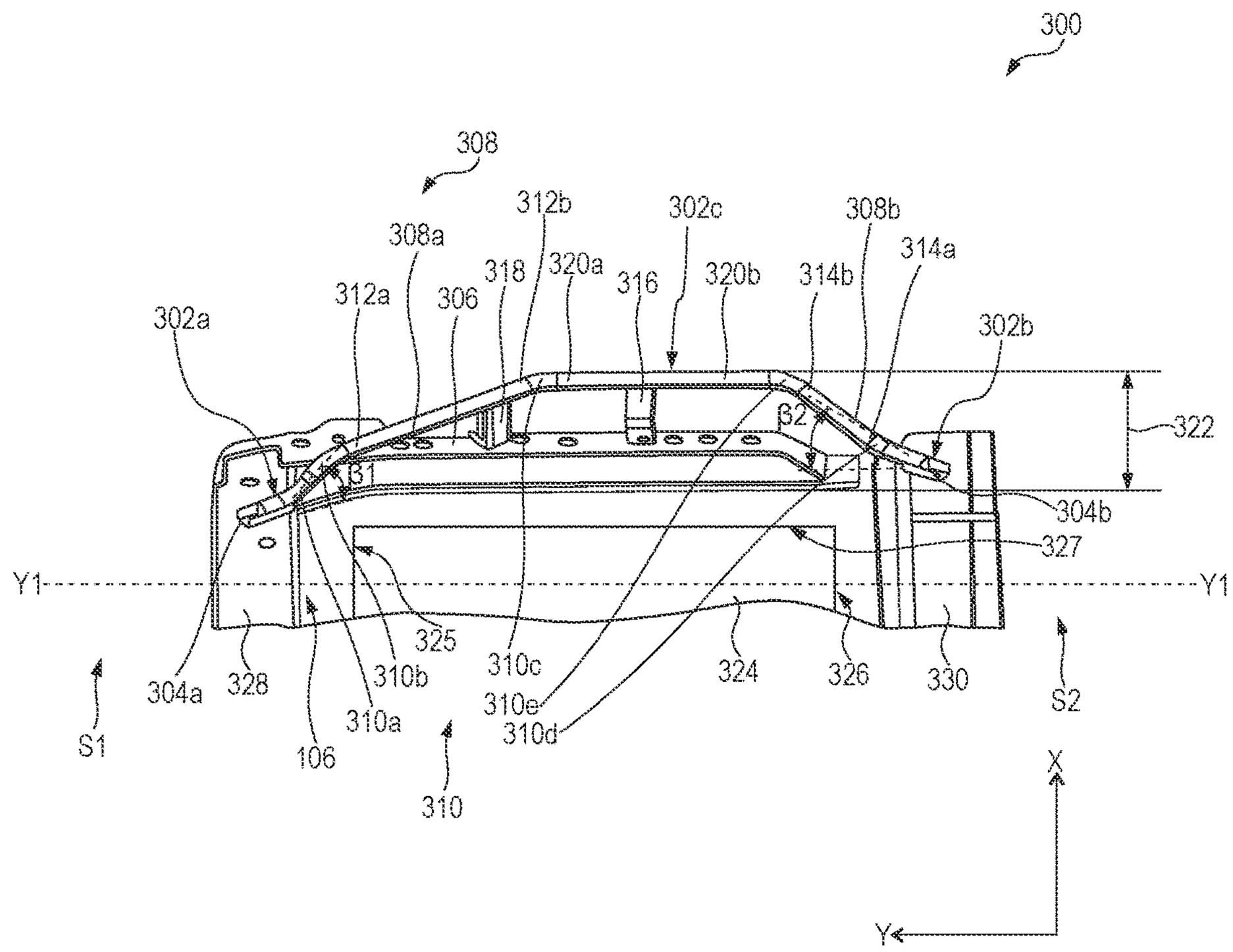

300
308
312b
302c
308b
308a
314a
318
320a
316
320b
314b
312a
306
302a
302b
322
β2
β1
304b
327
Y1
Y1
325
310c
324
326
330
304a
328
310b
310e
310a
310d
S1
S2
106
310
X
Y

FIG. 3

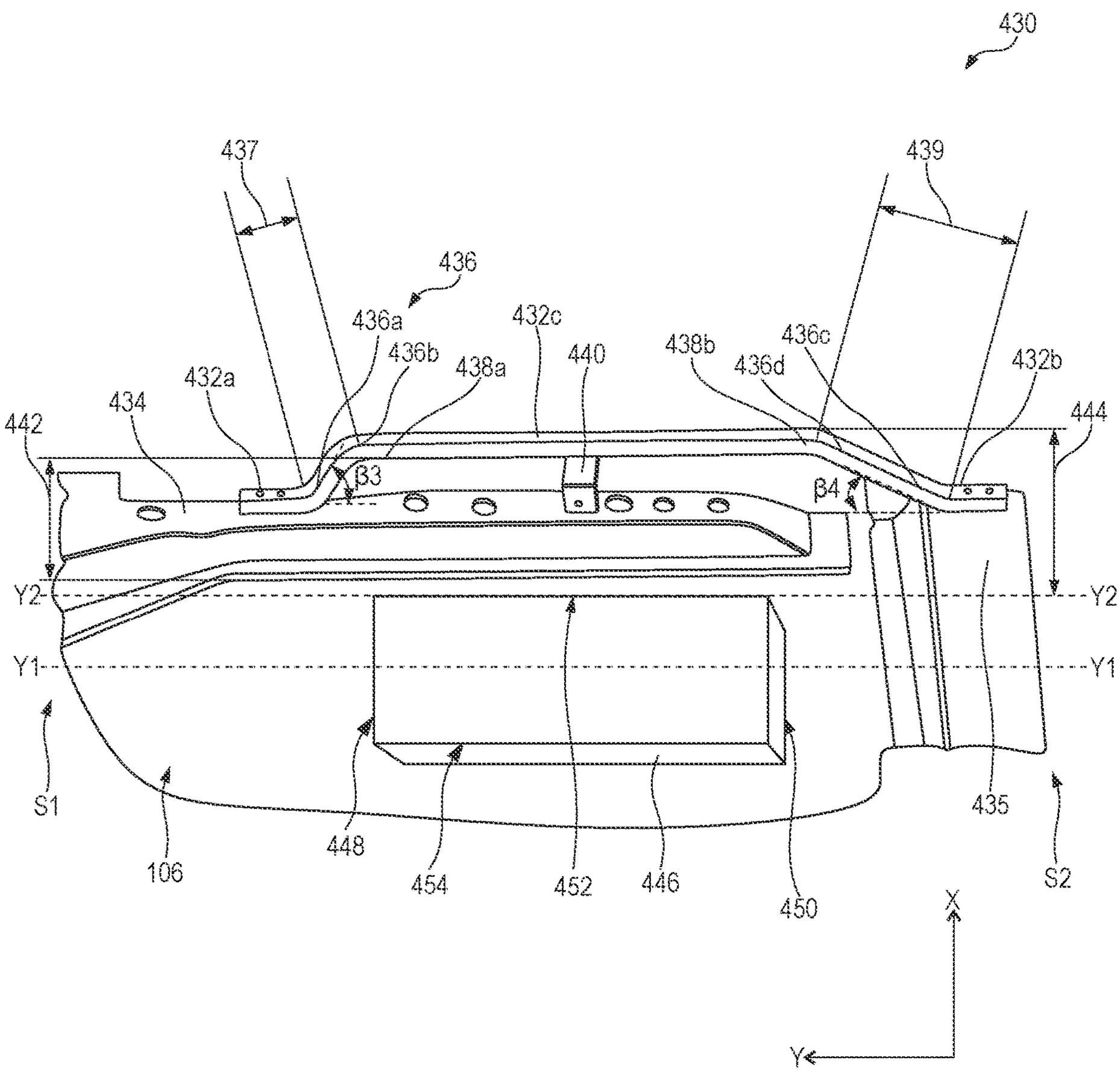

430
437
439
436
436a
436b
438a
432c
440
438b
436c
436d
432b
432a
434
442
444
β3
β4
Y2
Y1
S1
106
448
454
452
446
450
435
S2
X
Y

FIG. 4

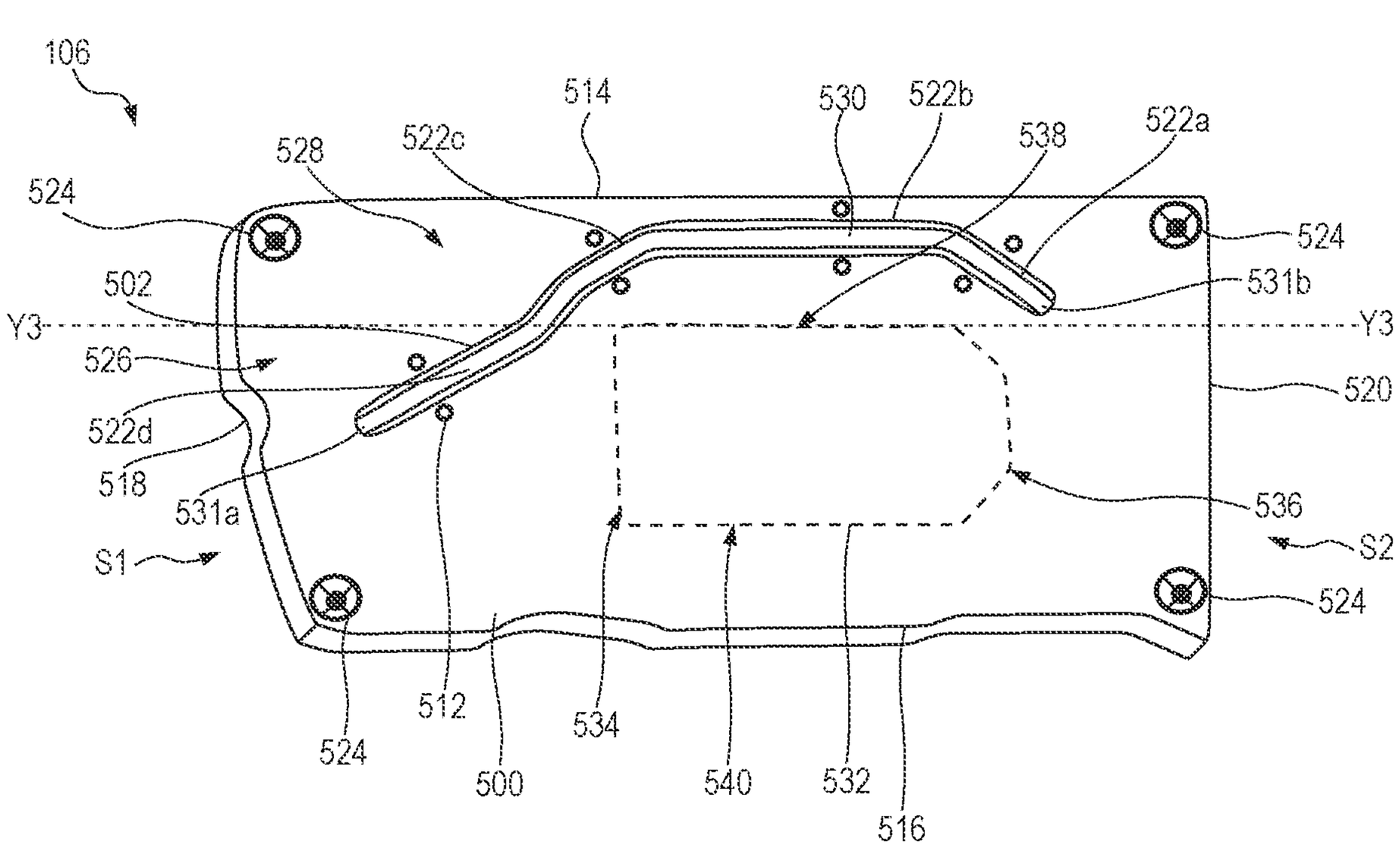

106
514
530
522b
538
522a
528
522c
524
524
502
531b
Y3
Y3
526
520
522d
518
536
531a
S2
S1
524
512
534
524
500
540
532
516

FIG. 5A

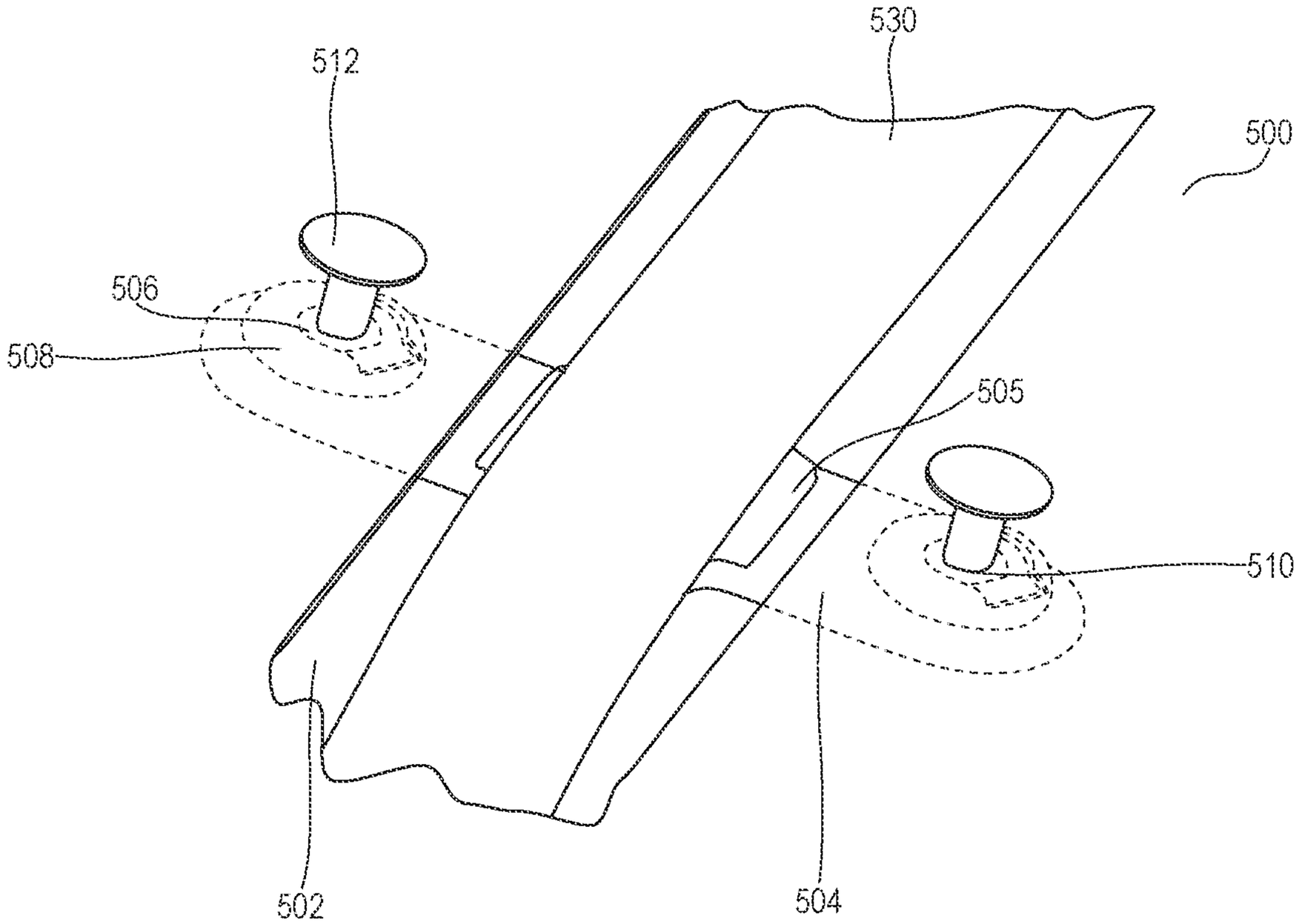


FIG. 5B

BATTERY PROTECTION IN AN ELECTRIC VEHICLE

BACKGROUND

Technical Field

The present disclosure relates to a slider bar for a battery pack of an electric vehicle.

Description of the Related Art

Battery packs may be mounted on an underside of an electric vehicle underbody positioned near a front axle. The battery pack protrudes towards the ground, which can impact an amount of ground clearance. Uneven roadways may interact with an exterior surface of the battery pack in some configurations and situations.

BRIEF SUMMARY

The present disclosure is directed to a slider bar assembly that separates a battery pack of a vehicle from the ground. The design and placement of the slider bar enables the slider bar to absorb ground impacts and minimizes the effect of the ground impact on the battery pack. The slider bar can be incorporated in electric vehicles having a longer wheelbase, such as trucks, sport utility vehicles, and crossover utility vehicles. The longer wheelbases may result in an exterior-most surface of the battery pack being closer to the ground. To maintain performance, the slider bar is positioned to separate the battery pack from a bulge or obstacle on a road surface or on a steep driveway or ramp.

The battery pack is positioned beneath an underbody in between a front axle and a rear axle. The battery pack extends from the underbody towards the ground. The slider bar is coupled to the underbody and extends further than the battery pack towards the ground. The slider bar will absorb ground impacts and keep the battery pack spaced from the ground.

The vehicle may include a shield or a battery pack cover that couples with the underbody and covers the battery pack. The shield includes a slot through which the slider bar extends past the battery pack. The slider bar is coupled with the underbody and the shield.

The slider bar is coupled to the underbody using a first end and a second end of the slider bar. The first end and the second end are each coupled to the underbody at least 30 cm away from both the front axle and the rear axle. The slider bar further includes an intermediate portion between the first end and the second end. The intermediate portion is a non-linear shape that curves or bends around a side of the battery pack.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1**A is a side view of a vehicle with a battery pack and a slider bar, according to an embodiment of the present disclosure;

FIG. **1**B is a simplified bottom view of an underbody with the battery pack and the slider bar of FIG. **1**A;

FIG. **2** is a slider bar adjacent to a battery, according to an embodiment of the present disclosure;

FIG. **3** is a bottom perspective view of a slider bar, according to an embodiment of the present disclosure;

FIG. **4** is another example of a slider bar, according to an embodiment of the present disclosure;

FIG. **5**A is a shield or a battery cover covering a battery pack and a slider bar, according to an embodiment of the present disclosure;

FIG. **5**B is a coupling mechanism (tabs) to couple the slider bar with the shield of FIG. **5**A.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various disclosed embodiments. However, one skilled in the relevant art will recognize that embodiments may be practiced without one or more of these specific details, or with other methods, components, materials, etc. In other instances, well-known structures or methods associated with vehicles have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

FIGS. **1**A and **1**B are views of a vehicle **100** with a slider bar **130** and a battery pack **120**, according to one embodiment. FIG. **1**A is a side view of the vehicle **100** and FIG. **1**B is a simplified view of an underside or an underbody **106** of the vehicle **100**.

The vehicle **100** may be an electric vehicle, a hybrid vehicle, a plug-in hybrid electric vehicle, or a battery electric vehicle. The battery pack **120** is positioned between a front axle **102** and a rear axle **104**. A set of rear tires **103***a*, **103***b* are coupled to the rear axle **104** and a set of front tires **115***a*, **115***b* are coupled to the front axle **102**. The battery or the battery pack **120** is affixed to the underside **106** of the body, which may correspond to a position of a passenger compartment **101**. The battery pack **120** includes a front edge **105** and a rear edge **107**. The slider bar **130** includes a first end **132***a* closer to the front axle **102** and a second end **132***b* that is closer to the rear axle **104**. The front edge **105** of the battery pack **120** is closer to the first end **132***a* of the slider bar **130**, and the rear edge **107** is closer to the second end **132***b*. The battery pack **120** may be positioned equidistant from the front axle **102** and the rear axle **104** or may be positioned closer to the front axle **102** than the rear axle **104**.

The underside or the underbody **106** provides a surface area and mechanical support for housing various components of the vehicle **100** such as electric motors, transmission, and suspension parts and supports an interior floor of the passenger compartment **101**, among other things. The underbody **106** includes a lower surface **110** that faces towards ground or roadway **112**. The battery pack **120** is coupled to the lower surface **110** of the underbody **106** that could include a recess for the battery pack **120** to be coupled within. Fasteners, adhesives, and other coupling techniques attach the battery pack **120** to the lower surface **110** of the underbody **106**. In one example, the underbody **106** includes holes or retaining openings that can receive fasteners to secure the battery pack **120** with flanges or extensions that include corresponding openings, see openings **111**.

As the battery pack **120** occupies space and is mounted under the underbody **106**, the battery pack **120** protrudes or otherwise extends below the underbody **106** towards the ground **112** and in a direction away from the underbody **106**. In FIG. **1**A, the battery pack **120** has a height H**1**, which corresponds to a distance between a bottom surface **122** of the battery pack **120** and the lower surface **110** of the underbody **106**. The height H**1** and dimensions of the battery pack **120** may vary depending on the type of batteries used to assemble the battery pack **120**.

The battery pack **120** provides power to various devices, including electric motors and other electrical components of the vehicle **100**. The battery pack **120** may include a set of batteries or individual battery cells configured in a series, a parallel or a hybrid combination, to deliver a voltage, capacity, or power density. The number of batteries and the number of individual battery cells used in the battery pack **120** may vary depending upon the type of vehicle **100**.

The ground clearance of the vehicle **100** is a distance between the bottom surface **122** of the battery pack **120** and the ground **112**. As a wheelbase of the vehicle **100** is increased, a ramp break over (RBO) angle is decreased. The RBO angle is an arc **114** between the front tires **115***a*, **115***b* and the rear tires **103***a*, **103***b* and lowest surface of components under the vehicle **100**. The RBO is dependent on the wheelbase, suspension height, tire size, and other floor body components of the vehicle **100**. The RBO angle identifies when the vehicle **100** will interact with the ground **112** when over steep driveway ramps, parking structure ramps, irregular and uneven roads, and off-road features, for example.

The slider bar **130** is coupled to the underbody **106**, in a proximity of the battery pack **120** to adjust the ground clearance of the vehicle **100**. The first end **132***a* and the second end **132***b* form proximal and distal ends of the slider bar **130**, respectively. The slider bar **130** includes a first portion **132***c* that extends from the first end **132***a* to a first curved portion **132***d*. The slider bar **130** further includes a second portion **132***e* that extends from the second end **132***b* to a second curved portion **132***f*. An intermediate portion **132***g* extends from the first curved portion **132***d* to the second curved portion **132***f* The first portion **132***c* is at a first angle with respect to a central axis Y**1**-Y**1** of the battery pack **120** that corresponds to a Y-axis. The first angle is, for example, in the range of 35 and 50 degrees. The second portion **132***e* is at a second angle with respect to the central axis Y**1**-Y**1** of the battery pack **120**. The second angle is smaller than the first angle. The second angle may be in the range of 20 and 30 degrees.

The first end **132***a* is coupled to the underbody **106** at a distance D**1** from the front axle **102**. The second end **132***b* is coupled to the underbody **106** at a distance D**2** from the rear axle **104**. The distances D**1** and D**2** generally vary between 30 to 50 centimeters (cm). The distance D**1** is greater than the distance D**2**. The distances D**1** and D**2** will vary depending on the type of the vehicle **100** (pickup, hatchback, sedan). Further, the slider bar **130** may be coupled to the underbody **106** using bolts, welding, fasteners, or any other suitable techniques.

The first end **132***a* is closer to the central axis Y**1**-Y**1** of the battery pack **120** than the second end **132***b* of the slider bar **130**. The first end **132***a* is closer to the central axis Y**1**-Y**1** of the battery pack **120** than an edge **109** of the battery pack **120**. The edge **109** is closer to a centerline C**1**-C**1** of the vehicle **100** and is opposite to another edge **113** that is along a passenger side S**4** of the vehicle **100**. The second end **132***b* is further from the central axis Y**1**-Y**1** of the battery pack **120** than the edge **109**. The intermediate portion **132***g* is the furthest feature of the slider bar **130** from the central axis Y**1**-Y**1** of the battery pack **120**.

In this embodiment, the battery pack **120** is positioned closer to the passenger side S**4** than a driver's side S**3**. The slider bar **130** is positioned between the battery pack **120** and the centerline C**1**-C**1** of the vehicle **100**. In some embodiments, the slider bar **130** may have the first and second ends **132***a, b* coupled to the passenger side S**4** of the centerline C**1**-C**1** of the vehicle **100**, while at least part of the intermediate portion **132***g* crosses or overlaps the centerline C**1**-C**1** of the vehicle **100**.

The first end **132***a* and the second end **132***b* help in offsetting the slider bar **130** laterally from the battery pack **120** by a distance L**1**. The offset distance is of a few centimeters (5-10 cm, for example). The slider bar **130** is offset away from the battery pack **120** towards a lateral edge **134** of the underbody **106**. As in FIG. **1**B, the slider bar **130** does not overlap the battery pack **120** when looking from a bottom view.

The slider bar **130** protrudes and extends outward below the underbody **106** towards the ground **112** and with a bottom surface **136** between the ground **112** and the battery pack **120**. This positioning allows a safe distance from the ground **112** to minimize damage to the battery **120**. The bottom surface **136** of the slider bar **130** is at a distance H**2** from the lower surface **110** of the underbody **106**. In all embodiments of the present disclosure, the distance H**2** is greater than the height H**1**. In an example, the distance H**2** is 5 mm to 10 mm more than the height H**1**, which means, if the height H**1** is 10 millimeters (mm), the distance H**2** is 15 mm to 20 mm.

The arrangement of the battery pack **120** and the slider bar **130** positions the slider bar **130** to impact the ground **112** to protect the battery pack **120** in the event the vehicle **100** bottoms out. Accordingly, the slider bar **130** protects the battery pack **120** from, for example, scratches, and impacts with the ground **112**. During the impacts, deflection of the slider bar **130** is controlled by its design (offsetting of the slider bar **130**) such that the slider bar **130** does not make contact with the battery pack **120**, even during maximum deflection. In order to ensure that the slider bar **130** has sufficient strength and a long service life, the slider bar **130** may be composed of materials such as high-strength steel, titanium, composites, aluminum, and/or combinations thereof.

The slider bar **130** is made hollow to reduce weight and be cost-effective, but in some examples, the slider bar **130** may be solid. The cross section of the slider bar **130** may be circular, rectangular, triangular, oval, square, or of any other suitable shape.

FIG. **2** is an alternative embodiment of a slider bar **230** arranged on the underside **106** of the vehicle **100** adjacent to the battery pack **120**, according to an embodiment of the present disclosure. The slider bar **230** includes a first end **232***a*, a second end **232***b*, and an intermediate portion **232***c*. The first end **232***a* and the second end **232***b* form proximal and distal ends of the slider bar **230**, respectively. The first end **232***a* is closer to the front edge **105** and the second end **232***b* is closer to the rear edge **107** of the battery pack **120**. The first end **232***a* is coupled to the underbody **106** and positioned between the front axle **102** of the vehicle **100**, illustrated in FIG. **1**B, and the front edge **105** of the battery pack **120**. The second end **232***b* is coupled to the underbody **106** and positioned between the rear axle **104** of the vehicle **100**, illustrated in FIG. **1**B, and the rear edge **107** of the battery pack **120**.

The slider bar **230** is an irregularly shaped beam that includes various straight members **240** and angled members **242** specifically selected to conform to a shape of the battery pack **120** and the associated vehicle **100**. The various combinations of the straight members **240** and the angled members **242** are selected based on various factors such as vehicle design, desired strength of the slider bar **230**, and sizing of the battery pack **120**.

The first end **232***a* of the slider bar **230** includes a first straight member **240***a* and three angled or angular members, i.e., **242***a*, **242***b*, and **242***c*. Similarly, the second end **232***b* of the slider bar **230** includes a second straight member **240***b* and two angled or angular members, i.e., **242***d* and **242***e*.

The first angular member **242***a* elevates the first end **232***a* from the underbody **106** to a first angle, with respect to the central axis Y**1**-Y**1** of the battery pack **120** and connects with the second angular member **242***b*. The first angle, for example, is in the range of 35 and 50 degrees. The second angular member **242***b* connects with a proximal end **244***a* of the first straight member **240***a*. The angular member **242***c* connects a distal end **244***b* (opposite to the proximal end **244***a*) of the first straight member **240***a* to a first portion **255***a* of the intermediate portion **232***c*. The first straight member **240***a* and the angular member **242***c* extend in a tilted or an angled manner along a straight line to achieve a vertical height up to the first portion **255***a* of the intermediate portion **232***c*. The angular member **242***c* is coupled to the first portion **255***a* of the intermediate portion **232***c* and is substantially parallel to the underbody **106**.

Similarly, the third angular member **242***d* elevates the second end **232***b* from the underbody **106** to a second angle with respect to the central axis Y**1**-Y**1** of the battery pack **120** that may be different from the first angle. The second angle, for example, is in the range of 35 and 50 degrees. In an implementation, the second angle is smaller than the first angle. In another implementation, the first and second angles are equal, that is the first and second ends **232***a* and **232***b* are structurally similar.

The angular member **242***d* connects with a proximal end **246***a* of the second straight member **240***b*. The angular member **242***e* connects a distal end **246***b* (opposite to the proximal end **246***a*) of the second straight member **240***b* to a second portion **255***b* of the intermediate portion **232***c*. The second straight member **240***b* and the angular member **242***e* extends in a tilted or an angled manner along a straight line to achieve the height up to the second portion **255***b* of the intermediate portion **232***c*. The angular member **242***e* is coupled to the second portion **255***b* of the intermediate portion **232***c* and is substantially parallel to the underbody **106**.

The first and second ends **232***a* and **232***b* integrally join to the intermediate portion **232***c*. The intermediate portion **232***c* is a straight solid bar and runs parallel to the underbody **106**. The design and arrangement of the straight members **240** and the angled members **242**, as described in the paragraphs above, help in offsetting the intermediate portion **232***c* laterally from the battery pack **120** by the distance L**1**.

The intermediate portion **232***c* is offset laterally by the distance L**1** from the battery pack **120** so that the intermediate portion **232***c* does not make contact with the battery pack **120** or high voltage (HV) wiring even under maximum deflection.

The first end **232***a* and the second end **232***b* are continuous structures with a constant cross-sectional area. The slider bar **230** has a substantially circular cross-sectional area. Alternatively, the first end **232***a* and the second end **232***b* may flatten out to flat bar structures **238***a* and **238***b* near the underbody **106**. The flat bar structures **238***a* and **238***b* may improve the overall strength of couplings. The flat bar structure **238***b* may be coupled to the underbody **106** on one side of the central axis Y**1**-Y**1** such that the structure **238***b* is closer to the edge **109** of the battery pack **120** compared to the edge **113**. The flat bar structure **238***a* is coupled on another side of the central axis Y**1**-Y**1** such that the structure **238***a* is closer to the edge **113** compared to the edge **109** of the battery pack **120**.

The intermediate portion **232***c* includes a bracket **248** that is coupled to the intermediate portion **232***c* at one end and to the underbody **106** at another end. The slider bar **230** may include multiple brackets to couple with the underbody **106** and support the slider bar **230** to absorb any potential impacts.

The intermediate portion **232***c* protects the battery pack **120** and the HV wiring when the vehicle **100** bottoms out. The battery pack **120** is also prevented from being impacted when the vehicle **100** travels on an uneven road surface, thereby, improving service life of the battery pack **120**.

The entirety of the slider bar **230** (the first end **232***a*, the second end **232***b*, and the intermediate portion **232***c*) is manufactured as a single unit via casting, forming, additive manufacturing, or by any other suitable process. Alternatively, the first end **232***a*, the second end **232***b*, and the intermediate portion **232***c* can be manufactured separately and be coupled using a suitable method like welding, for example. Also, the materials of the slider bar **230** may be composed of high-strength steel, titanium, composites, aluminum, and/or combinations thereof. The slider bar **230** may further include an abrasive coating of rubber or an anti-rust material. This may increase the service life of the slider bar **230** and improves its corrosion resistance.

FIG. **3** is a perspective view of an alternative embodiment of a slider bar **300** arranged on the underside **106** of the vehicle **100** adjacent to a battery pack **324**, according to an embodiment of the present disclosure. FIG. **3** is a simplified perspective view that shows only an outline of the battery pack **324** for the purpose of beverity. The battery pack **324** includes an edge **325** and an edge **326** that is parallel to the edge **325**. The edge **325** is closer to the front axle **102** compared to the rear axle **104** of the vehicle **100**, and the edge **326** is closer to the rear axle **104** compared to the front axle **102** of the vehicle **100**. The battery pack **324** includes an edge **327** and another edge (not shown) that is parallel to the edge **327**. The edge **327** is closer to the slider bar **300** compared to the another edge.

The slider bar **300** includes a first end **302***a*, a second end **302***b*, and an intermediate portion **302***c*. The first end **302***a* and the second end **302***b* form proximal and distal ends of the slider bar **300**, respectively. The first end **302***a* is closer to the front edge **325** and the second end **302***b* is closer to the rear edge **326** of the battery pack **324**. The first end **302***a* is coupled to the underbody **106** and positioned between the front axle **102** of the vehicle **100** and the front edge **325** of the battery pack **324**. The second end **302***b* is coupled to the underbody **106** and positioned between the rear axle **104** of the vehicle **100** and the rear edge **326** of the battery pack **324**. The first end **302***a* and the second end **302***b* of the slider bar **300** are coupled on frame elements **328**, **330**, respectively.

The slider bar **300** is irregularly shaped and includes multiple straight members **308** and angled members **310** that allow the slider bar **300** to conform to a shape of the battery pack **324** and the associated vehicle **100**. The combinations of the straight members **308** and the angled members **310** are selected based on various factors such as vehicle design, desired strength of the slider bar **300**, and sizing of the battery pack **324**.

The first end **302***a* of the slider bar **300** includes a first straight member **308***a* and three angled or angular members, i.e., **310***a*, **310***b*, and **310***c*. Similarly, the second end **302***b* of the slider bar **300** includes a second straight member **308***b* and two angled or angular members, i.e., **310***d* and **310***e*.

The angular member **310***a* elevates the first end **302***a* from the underbody **106** to a first angle β**1** that may be in the range of 35 and 50 degrees, for example 45 degrees, with respect to a central axis Y**1**-Y**1** of the battery pack **324** and connects with the angular member **310***b*. A proximal end **312***a* of the first straight member **308***a* connects with the angular member **310***b*. The angular member **310***c* connects a distal end **312***b* (opposite to the proximal end **312***a*) of the first straight member **308***a* to a first portion **320***a* of the intermediate portion **302***c*. The first straight member **308***a* and the angular member **310***c* extend in a tilted or an angled manner along a straight line to achieve a vertical height **322** up to the first portion **320***a* of the intermediate portion **302***c*. The angular member **310***c* is coupled to the first portion **320***a* of the intermediate portion **302***c* and is substantially parallel to the underbody **106**.

Similarly, the angular member **310***d* elevates the second end **302***b* from the underbody **106** to a second angle β**2** that may be in the range of 35 and 50 degrees, for example 30 degrees, with respect to the central axis Y**1**-Y**1** of the battery pack **324**. The angular member **310***d* connects with a proximal end **314***a* of the second straight member **308***b*. The angular member **310***e* connects a distal end **314***b* (opposite to the proximal end **314***a*) of the second straight member **308***b* to a second portion **320***b* of the intermediate portion **302***c*. The second straight member **308***b* and the angular member **310***e* extend in a tilted or an angled manner along a straight line to achieve the vertical height **322**. The angular member **310***e* is coupled to the second portion **320***b* of the intermediate portion **302***c* and is substantially parallel to the underbody **106**. In one embodiment, the first and the second acute angles β**1** and β**2** are the same, i.e., the first end **302***a* is structurally similar to the second end **302***b*.

The first and second ends **302***a* and **302***b* integrally join the intermediate portion **302***c*, which is a straight solid bar and runs parallel to the underbody **106**. The intermediate portion **302***c* is laterally offset from the battery pack **324** so that the intermediate portion **302***c* does not make contact with the battery pack **324** or HV wiring even under maximum deflection.

A first support **304***a*, a second support **304***b*, and one or more frame elements **306** may be coupled to the underbody **106**. The first end **302***a* of the slider bar **300** is coupled with the first support **304***a* and the second end **302***b* of the slider bar **300** is coupled with the second support **304***b*, opposite to the first support **304***a*. The first support **304***a* and the second support **304***b* are thin flattened strips that increase the mechanical strength of couplings. The first end **302***a* and the second end **302***b* are coupled to the first support **304***a* and the second support **304***b*, respectively. In one example, the first support **304***a* and the second support **304***b* are a part of the frame element **306** of the underbody **106**. In one example, the frame element **306** is a sheet metal.

The first end **302***a* and the second end **302***b* of the slider bar **300** may be continuous structures with a constant cross-sectional area. The slider bar **300** has a substantially circular cross-sectional area. The first end **302***a* and the second end **302***b* may be coupled to the frame elements **328**, **330** of the underbody **106** on only one side of the central axis Y**1**-Y**1** of the battery pack **324** such that the first and second ends **302***a,b* are closer to the edge **327** compared to an opposing edge (not shown) of the battery pack **324**.

The intermediate portion **302***c* includes a first bracket **316** and a second bracket **318**. The first bracket **316** is coupled to the intermediate portion **302***c* at one end and to the frame element **306** at another end. The first and the second brackets **316**, **318** are manufactured with the entire slider bar **300** as a single unit. Alternatively, the brackets **316** and **318** may be manufactured as separate components and attached to the slider bar **300** using suitable techniques. The slider bar **300** may include multiple brackets or a single bracket to couple with the underbody **106** and support the slider bar **300** to absorb any potential impacts.

The slider bar **300** may include materials and may be manufactured in ways that are similar to as discussed in FIG. **2**.

FIG. **4** is an alternative embodiment of a slider bar **430** adjacent to a battery pack **446** according to the present disclosure. The slider bar **430** is a straight tubular structure having a substantially rectangular cross section.

The slider bar **430** includes a first end **432***a*, a second end **432***b*, and an intermediate portion **432***c* that is between the first and second ends **432***a, b*. The first end **432***a* and the second end **432***b* form proximal and distal ends of the slider bar **430**, respectively. The battery pack **446** includes an edge **448** and an edge **450** that is parallel to the edge **448**. The edge **448** is closer to the front axle **102** compared to the rear axle **104** and the edge **450** is closer to the rear axle **104** compared to the front axle **102**. The battery pack **446** includes an edge **452** and an edge **454** that is parallel to the edge **452**. The edge **452** is closer to the slider bar **430** compared to the edge **454**. An edge axis line Y**2**-Y**2** that runs from the front side S**1** to the rear side S**2** of the vehicle **100**, corresponds to the edge **452** of the battery pack **446**. The first end **432***a*, the second end **432***b*, and the intermediate portion **432***c* of the slider bar **430** are positioned further from a central axis Y**1**-Y**1** of the battery pack **446** than the outermost edge **452** of the battery pack **446** and the edge axis line Y**2**-Y**2**. The first end **432***a* and the second end **432***b* of the slider bar **430** are coupled on frame elements **434**, **435** that are coupled to the underbody **106** and add to a distance **444** to create sufficient separation from the battery pack **446**.

The first end **432***a* and the second end **432***b* of the slider bar **430** are coupled at least 50 cm away from both the front and the rear axles, **102** and **104**, respectively, illustrated in FIG. **1**B. Additionally, the slider bar **430** is coupled such that the intermediate portion **432***c* is located at the distance **444** from the battery pack **446**. The distance **444** is the lateral distance between the battery pack **446** and a battery-facing surface of the intermediate portion **432***c*.

The first end **432***a* and the second end **432***b* include angular members **436**. The angular members **436** (also called angled members **436**) can be altered according to design requirements such as desired strength of the slider bar **430** and sizing of battery pack **446**.

The angled members **436** include a first angular member **436***a* and a second angular member **436***b* at the first end **432***a*. The first angular member **436***a* elevates the first end **432***a* from the underbody **106** to a third acute angle β**3** (e.g., 50-65 degrees) with respect to the central axis Y**1**-Y**1** of the battery pack **446**, so that the first end **432***a* achieves a height **442**. The first end **432***a* is flat and coupled to the frame element **434**. The tube is bent at the first angular member **436***a* away from the underbody **106**. The second angular member **436***b* is bent in a different direction than the first angular member **436***a*. The second angular member **436***b* is coupled to a first portion **438***a* of the intermediate portion **432***c* and is substantially parallel to the underbody **106**.

Similar to the first end **432***a*, the angled members **436** include a third angular member **436***c* and a fourth angular member **436***d* that are closer to the second end **432***b*. The third angular member **436***c* elevates the second end **432***b* from the underbody **106** to a fourth acute angle β**4** (e.g., 30-45 degrees) with respect to the central axis Y**1**-Y**1** of the

battery pack **446**, so that the second end **432***b* achieves the height **442**. The second end **432***b* is flat and coupled to the frame member **435**. The first end **432***a* and the second end **432***b*, may be at a same distance from the central axis Y**1**-Y**1** of the battery pack **446**.

The third angular member **436***c* curves or bends away from the second end **432***b* and away from the underbody **106**. The fourth angular member **436***d* bends in a different direction than the third angular member **436***c*. A second portion **438***b* of the intermediate portion **432***c* extends from the fourth angular member **436***d* and is substantially parallel to the underbody **106**.

A distance **437** between the first and second angular members **436***a* and **436***b* is less than a distance **439** between the third and fourth angular members **436***c* and **436***d*. The third angle β**3** is greater than the fourth angle β**4**. The first and second portions **438***a* and **438***b*, as explained above, integrally join to the intermediate portion **432***c*. The intermediate portion **432***c* is a straight solid bar and runs substantially parallel to the underbody **106**. The intermediate portion **432***c* is laterally spaced apart from the edge **452** of the battery pack **446** by the distance **444**. The distance **442** between the intermediate portion **432***c* and the battery pack **446** is configured to separate the battery pack **446** from the ground **112**, illustrated in FIG. **1**A, with the intermediate portion **432***c* even if there is deflection of the slider bar **430** upon impact with the ground **112** or an object.

The intermediate portion **432***c* is coupled to the underbody **106** with a bracket **440**. The bracket **440** is between the first end **432***a* and the second end **432***b* and is spaced from the edge **452** by the distance **444**. The bracket **440** may be coupled to the frame member **434** with a fastener or other coupling device.

The intermediate portion **432***c* of the slider bar **430** is closer to the ground **112** than the battery pack **446**. In an event of the vehicle **100** bottoming out, the impact will be absorbed by the slider bar **430** and the battery pack **446** will be protected.

FIGS. **5**A and **5**B illustrate a slider bar **530** protruding from a shield **500**, according to one embodiment of the present disclosure. The slider bar **530** is a non-linear bar that is coupled to the underbody **106** of the vehicle **100** with ends that are covered by the shield **500**. The shield **500** includes an opening or a slot **502** through which the bar **530** can extend by a distance. Only a surface of the bar **530** extends through the opening **502**. The surface of the bar **530** is configured to interact with the ground **112**, illustrated in FIG. **1**A, separating a cover and a battery **532** from interacting with the ground **112**. The battery pack **532** includes an edge **534** and an edge **536** that is parallel to the edge **534**. The edge **534** is closer to the front axle **102** compared to the rear axle **104**, illustrated in FIG. **1**B, and the edge **536** is closer to the rear axle **104** compared to the front axle **102**. The battery pack **532** includes an edge **538** and an edge **540** that is parallel to the edge **538**. The edge **538** is closer to the slider bar **530** compared to the edge **540**.

The shield **500** is a cover or other physical structure that encloses the battery pack **532** and other related components to keep road debris and dust away. The shield **500** may be plastic, a plurality of composites, carbon fiber, sheet metals, or other suitable materials. The shield **500** is coupled on the underbody **106** and covers the entire battery pack **532** and high voltage wiring, for example. The shield **500** is coupled on the underbody **106** using one or more fasteners **524**.

The dimensions of the shield **500** may be varied to accommodate different sizes of vehicles, battery packs, or the slider bars. For example, if a longitudinal length of the battery pack **532** along the underbody **106** is increased or decreased, then, length of the shield **500** will be increased or decreased proportionally to that of the longitudinal length of the battery pack **532** so that the shield **500** always fully encloses the battery pack **532**.

The shield **500** includes a driver side or a first side **514**, a passenger side or a second side **516**, a front-end side or a third side **518**, and a rear-end side or a fourth side **520**. The second side **516** includes one or more curvatures and is not parallel to the first side **514**. Alternatively, the second side **516** can be parallel to the first side **514**. Similarly, the third side **518** or the fourth side **520** may include curvatures and may not be parallel to each other. Alternatively, the third side **518** and the fourth side **520** can be parallel to each other.

The shield **500** includes the groove or the slot **502** shaped to accommodate the protruding slider bar **530**. The dimensions of the slot **502** are slightly bigger than the slider bar **530** such that the slider bar **530** can easily extend through the slot **502**. The slider bar **530** extends outwards towards the ground **112** through the slot.

The slot **502** includes sections **522***a*, **522***b*, **522***c*, and **522***d* that correspond to the shape and contour of the slider bar **530** that shall be positioned inside. An edge axis line Y**3**-Y**3**, that runs from the front side S**1** to the rear side S**2** of the vehicle **100**, corresponds to the edge **538** of the battery **532**. The edge axis line Y**3**-Y**3** intersects the slot **502** to form a first section **526** and a second section **528** of the slot **502**. The first section **526** includes a first end **531***a* of the slider bar **530**, the section **522***d*, and a portion of the section **522***c* of the slot **502**. The second section **528** includes a portion of the section **522***c*, the sections **522***a*, **522***b* of the slot **502**, and a second end **531***b* of the slider bar **530**. The first section **526** is located ahead of the edge **534** of the battery **532**, towards the front axle **102**. The second section **528** is located beside or adjacent to the edge **538** of the battery **532**. The second section **528** is closer to the centerline C**1**-C**1**, illustrated in FIG. **1**B, compared to the first section **526**. The second section **528** extends between the front axle **102** and the rear axle **104**, illustrated in FIG. **1**B.

As shown in FIG. **5**B, the slider bar **530** includes a plurality of tabs **504** installed on the surface to couple with the shield **500**. The tabs **504** are sheet metal pieces and are attached to the slider bar **530** using any suitable technique, for example, welding. Optionally, the tabs **504** may be manufactured along with the slider bar **530** as a single unit. The tabs **504** are positioned perpendicularly on circumference of the slider bar **530** facing towards the battery pack **532**. The tabs **504** are spaced apart on the slider bar **530** at appropriate distances to effectively support the slider bar **530** and shield **500** coupling. The tabs **504** may include secondary structures **505** for gripping the slider bar **530**.

The tabs **504** include holes **506** and retainers **508**, such as washers or countersinks, for example. The holes **506** and the retainers **508** align with holes **510** on the surface of the shield **500**, located near the slot **502**. A bolt or a pin **512** is used to traverse through the holes **506**, **510** and the tabs **504**, respectively. The pin **512** effectively secures the slider bar **530** and the shield **500**.

As the shield **500** is coupled onto the battery pack **532**, the ground clearance below the battery pack **532** is further decreased by a few millimeters. The distance between a bottom surface of the shield **500** to the underbody **106** is a first height. A height of the slider bar **530** is greater than the first height, thereby ensuring that the slider bar **530** is present below the shield **500** and the battery pack **532**, with respect to the lower surface **110** of the underbody **106**. In the event the vehicle **100** bottoms out, the slider bar **530** makes

contact with the road features (e.g., driveway ramps) instead of the battery pack **532** enclosed within the shield **500**; thus ensuring the battery pack **532** is protected from scratches or scrapes from the ground and thereby.

The various embodiments described above can be combined to provide further embodiments. All of the U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet are incorporated herein by reference, in their entirety. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

The invention claimed is:

1. A vehicle, comprising:
a front axle;
a rear axle;
an underbody;
a battery pack coupled to the underbody between the front axle and the rear axle; and
a slider bar coupled to the underbody, the slider bar being closer to the ground than the battery pack,
wherein the slider bar does not overlap the battery pack when viewed from a bottom view of the vehicle.

2. The vehicle of claim **1**, further comprising a shield coupled to the underbody and covering the battery pack.

3. The vehicle of claim **2**, wherein the shield includes a slot, the slider bar protruding through the shield through the slot.

4. The vehicle of claim **3**, further comprising a plurality of tabs welded to the slider bar.

5. The vehicle of claim **4**, wherein the tabs are coupled to the shield.

6. The vehicle of claim **5**, wherein the tabs are sheet metal, the slider bar is steel, the shield is plastic, and the underbody includes sheet metal.

7. The vehicle of claim **1**, wherein the slider bar includes:
a first end coupled at least 50 cm away from the front axle and the rear axle; and
a second end coupled at least 50 cm away from the front axle and the rear axle.

8. A vehicle, comprising:
a front axle;
a rear axle;
an underbody;
a battery pack coupled to the underbody between the front axle and the rear axle; and
a slider bar including:
a first end coupled to the underbody at least 30 cm away from the front axle and the rear axle;
a second end coupled to the underbody at least 30 cm away from the front axle and the rear axle; and
an intermediate portion between the first end and the second end and extending below the underbody lower than the battery pack,
wherein the slider bar does not overlap the battery pack when viewed from a bottom view of the vehicle.

9. The vehicle of claim **8**, wherein the first end and the second end are each coupled to the underbody at least 50 cm away from both the front axle and the rear axle.

10. The vehicle of claim **8**, wherein the first end and the second end are bolted to the underbody.

11. The vehicle of claim **8**, further comprising a bracket coupled to the underbody and the intermediate portion.

12. The vehicle of claim **8**, wherein the intermediate portion is offset laterally from the battery pack.

13. The vehicle of claim **8**, wherein the slider bar has a substantially rectangular cross section.

14. The vehicle of claim **8**, wherein the slider bar has a substantially circular cross section.

15. The vehicle of claim **1**, wherein an intermediate portion of the slider bar is disposed axially between a lateral edge of the battery pack and a centerline of the vehicle.

16. The vehicle of claim **15**, wherein the intermediate portion extends between a first end and a second end of the slider bar, and further wherein the first end is coupled to the underbody at a first distance from the front axle and the second end is coupled to the underbody at a second distance from the rear axle.

17. The vehicle of claim **16**, wherein the first distance is greater than the second distance.

18. The vehicle of claim **16**, wherein the first end is coupled to the underbody at a first location that is a greater distance from the centerline of the vehicle than a second location at which the second end is coupled to the underbody.

19. A vehicle, comprising:
a front axle;
a rear axle;
an underbody;
a battery pack coupled to the underbody between the front axle and the rear axle; and
a slider bar coupled to the underbody and including a first end, a second end, and an intermediate portion between the first end and the second end,
wherein the first end is laterally offset a first distance from a central axis of the battery pack, the second end is laterally offset a second distance from the central axis, and the intermediate portion is laterally offset a third distance from the central axis,
wherein the second distance is greater than the first distance, and the third distance is greater than the second distance such that the intermediate portion establishes a furthest feature of the slider bar from the central axis,
wherein the slider bar does not overlap the battery pack when viewed from a bottom view of the vehicle.

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